Wind Loads During Construction

A Hands-On Lesson for Designing Partially Constructed Bridges Subject to Wind Loading

Check this session's schedule page within our app for access.

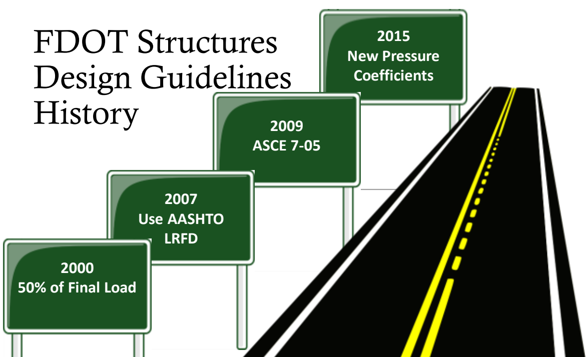
Why are you interested in learning about Wind Loads During Construction?

Guidebook Poll

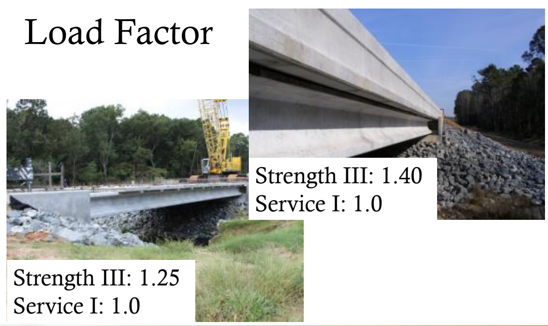
What Will You Learn?

- Code History
- Current Requirements
- Research and Development of Pressure Coefficient
- Differences for Florida Design from AASHTO LRFD Bridge Design Specifications
- How to Apply FDOT Requirements

FDOT Structures Design Guidelines History



Load Factor



Construction Active:

20 MPH Wind Speed

Construction Inactive:

Basic Wind Speed (110 - 150 MPH) With Reduction Factor

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FDOT Design Wind Pressure Equation

$$P_Z := 2.56x10^{-6} K_Z V^2 G C_P$$

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Velocity Pressure Exposure Coefficient

$$K_Z := 2.01\left({}^{Z}/_{900}\right)^{.2105} \geq 0.85$$

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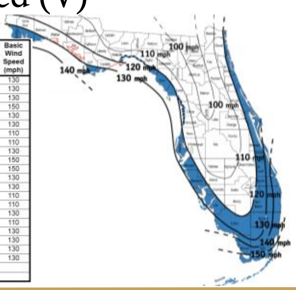
Basic Wind Speed (V)

County (Dist)	Basic Wind Speed (mph)	County (Dist)	Basic Wind Speed (mph)	County (Dist)	Basic Wind Speed (mph)
Alachua (2)	110	Hardee (1)	110	Okeechobee (1)	130
Baker (2)	110	Hendry (1)	130	Orange (5)	130
Bay (3)	130	Hernando (7)	130	Osceola (5)	130
Bradford (2)	110	Highlands (1)	130	Palm Beach (4)	150
Brevard (5)	130	Hillsborough (7)	130	Pasco (7)	130
Broward (4)	150	Holmes (3)	130	Pinellas (7)	130
Calhoun (3)	130	Indian River (4)	150	Polk (1)	110
Charlotte (1)	130	Jackson (3)	110	Putnam (2)	110
Citrus (7)	130	Jefferson (3)	110	St. Johns (2)	130
Clay (2)	110	Lafayette (2)	110	St. Lucie (4)	150
Collier (1)	150	Lake (5)	110	Santa Rosa (3)	150
Columbia (2)	110	Lee (1)	130	Sarasota (1)	130
DeSoto (1)	130	Leon (3)	110	Seminole (5)	130
Dixie (2)	130	Levy (2)	130	Sumter (5)	110
Duval (2)	130	Liberty (3)	130	Suwannee (2)	110
Escambia (3)	150	Madison (2)	110	Taylor (2)	130
Flagler (5)	130	Manatee (1)	130	Union (2)	110
Franklin (3)	130	Marion (5)	110	Volusia (5)	130
Gadsden (3)	110	Martin (4)	150	Wakulla (3)	130
Gilchrist (2)	110	Miami-Dade (6)	150	Walton (3)	130
Glades (1)	130	Monroe (6)	150	Washington (3)	130
Gulf (3)	130	Nassau (2)	130		
Hamilton (2)	110	Okaloosa (3)	130		



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Gust Effect Factor (G)

- G = 0.85 for ground mounted noise walls, perimeter walls and bridges with:
  - spans < 250 feet, and
  - height < 75 feet
- Otherwise evaluate according to ASCE/SEI 7-05 Section 6.5.8

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FDOT Wind Equation

$$P_Z := 2.56x10^{-6}K_Z V^2 G C_P$$

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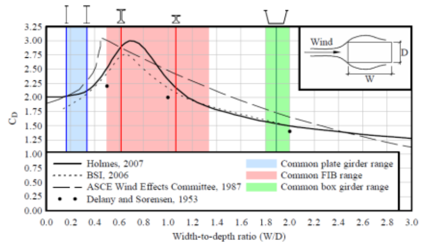
2009 Pressure Coefficient



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Research Objectives

- Determine applicable pressure coefficients to use for:
  - Girder Design
  - Cross-Frame Design
  - Substructure Reaction

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Wind Tunnel Test

Source: Consolazio, G.R., Gurley, K.R., and Harper, Z.S. (2013) *Bridge Girder Drag Coefficients and Wind-Related Bracing Recommendations*

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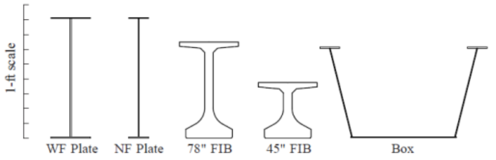
Tested Cross-Sections



Source: Consolazio, G.R., Gurley, K.R., and Harper, Z.S. (2013) *Bridge Girder Drag Coefficients and Wind-Related Bracing Recommendations*

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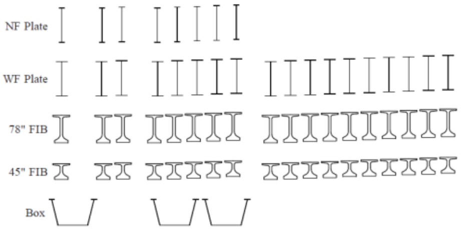
Tested Configurations



Source: Consolazio, G.R., Gurley, K.R., and Harper, Z.S. (2013) *Bridge Girder Drag Coefficients and Wind-Related Bracing Recommendations*

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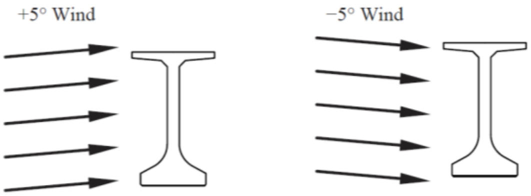
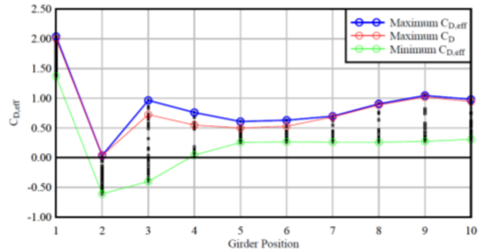
Tested Wind Angle



Source: Consolazio, G.R., Gurley, K.R., and Harper, Z.S. (2013) *Bridge Girder Drag Coefficients and Wind-Related Bracing Recommendations*

Results for Florida I Beams



Source: Consolazio, G.R., Gurley, K.R., and Harper, Z.S. (2013) *Bridge Girder Drag Coefficients and Wind-Related Bracing Recommendations*

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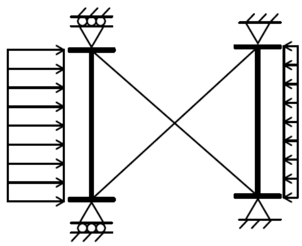
Negative Pressures



Source: Consolazio, G.R., Gurley, K.R., and Harper, Z.S. (2013) *Bridge Girder Drag Coefficients and Wind-Related Bracing Recommendations*

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Proposed Pressure Coefficient

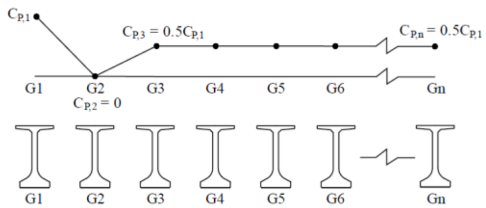

Figure 5.16 Proposed wind load shielding model for stability evaluation

Source: Consolazio, G.R., Gurley, K.R., and Harper, Z.S. (2013) *Bridge Girder Drag Coefficients and Wind-Related Bracing Recommendations*

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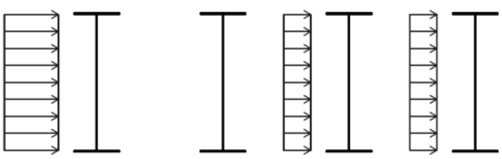
Wind Application



Source: Consolazio, G.R., Gurley, K.R., and Harper, Z.S. (2013) *Bridge Girder Drag Coefficients and Wind-Related Bracing Recommendations*

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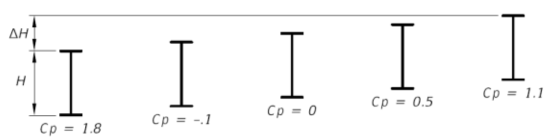
Revising the Pressure Coefficient



$$Global\ Cp = \frac{\sum Cp \times H}{(H + \Delta H)}$$

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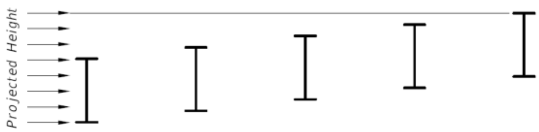
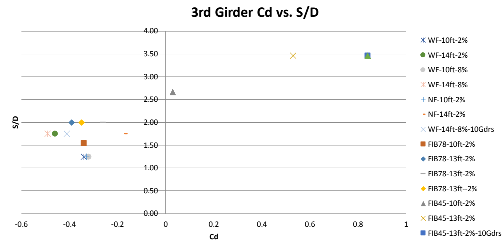
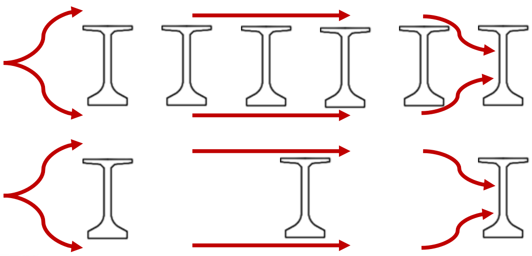
Wind Application



S/D Evaluation



Shielding Per S/D Ratio



Final Pressure Coefficient

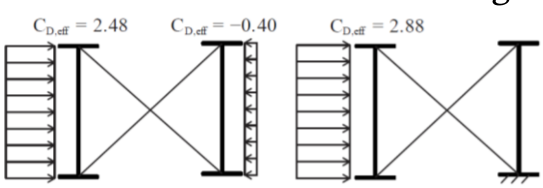
	Component Type	Pressure Coefficient (C_p)				
		S/D ≤ 3		S/D > 3		
		Girders 1-5	Girder 6+	Girder 1	Girder 2	Girder 3+
Superstructure	I-Shaped Steel Girder	2.2	1.1	2.5	0	1.1
Superstructure	I-Shaped Concrete Girder	2.0	1.0	2.0	0	1.0
Superstructure	U-Shaped Girder	2.2				
Superstructure	Flat Slab or Segmental Box Girder	1.5				
Substructure		1.6				

Where:

- S = Girder Spacing (ft)
- D = Girder Depth (ft)

Source: 2015 FDOT Structures Manual

Pressure Coefficient for Bracing

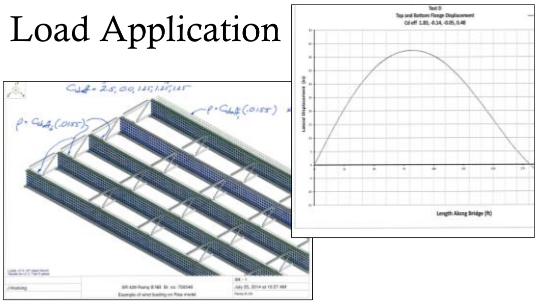


Component Type	Pressure Coefficient (C_p)
I-Shaped Steel Girder	2.9
I-Shaped Concrete Girder	2.6
U-Shaped Girder	3.3

FDOT Wind Equation

$$P_Z := 2.56x10^{-6} K_Z V^2 G C_P$$

Load Application



Design Example 1: Steel Girder Bridge

You are designing a bridge carrying I-10 over the Apalachicola River between Jackson and Gadsden Counties. The bridge consists of three spans with lengths of 170'-210'-170'. The superstructure is a steel I-girder with 7.5' girder depth. There are 5 girders at 9' spacing with a 2% cross-slope. Cross-frames are spaced at 25 feet. The bottom of the girders is 40 feet above the ground and normal water elevation. Assume construction will take 2 years and after the Contractor starts girder erection, there will be 6 weeks before the deck is poured.

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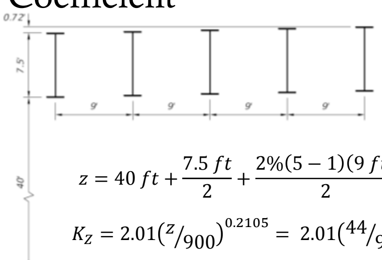
Velocity Pressure Exposure Coefficient



$$z = 40\,ft + \frac{7.5\,ft}{2} + \frac{2\%(5-1)(9\,ft)}{2} = 44.1\,ft$$

$$K_z = 2.01\left({}^{z}/_{900}\right)^{0.2105} = 2.01\left({}^{44}/_{900}\right)^{0.2105} = 1.065$$

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What is the Gust Effect Factor for this Example Bridge?

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Gust Effect Factor

- Since span is less than 250 ft and height is less than 75 feet, G = 0.85 per SDG section 2.4.1.E

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Pressure Coefficient

- The spacing to depth ratio is:

$$S/_D = {}^{9\,ft}/_{7.5\,ft} = 1.2 \leq 3$$

- Since the spacing to depth ratio is less than 3, C_P = 2.2, applied to the projected height of the girders

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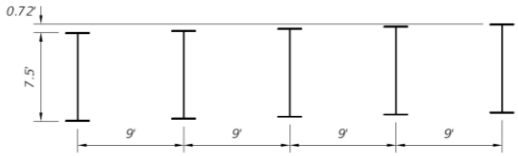
Projected Height

$Projected\ Height = 7.5\ ft + 2\%(5-1)(9\ ft) = 8.2\ ft$



Construction Active Wind Load

- Per SDG Table 2.4.3-1, V = 20 MPH for Construction Active

$$P_Z := 2.56x10^{-6} K_Z V^2 G C_P$$
$$= 2.56x10^{-6}(1.065)(20^2)(0.85)(2.2)$$
$$= 0.002\ ksf$$

$$w = (0.002\ ksf)(8.2\ ft) = 0.02\ klf$$

What is the Construction Inactive Wind Speed for this Example Bridge?

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Construction Inactive Wind Speed

- Per SDG Table 2.4.1-2, the basic wind speed for Jackson and Gadsden counties is 110 MPH.
- Per SDG section 2.4.3.C, since the exposure period is less than 1 year, $R_E = 0.6$.

$$V = (Basic\ Wind\ Speed)R_E = (110\ MPH)(0.6)$$
$$= 66\ MPH$$

Construction Inactive Wind Load

$$P_Z := 2.56x10^{-6} K_Z V^2 G C_P$$
$$= 2.56x10^{-6}(1.065)(66^2)(0.85)(2.2)$$
$$= 0.022\ ksf$$

$$w = (0.022\ ksf)(8.2\ ft) = 0.18\ klf$$

Substructure Reaction

- Use the previously calculated construction inactive wind load, w = 0.18 klf

End Bent Reaction:

$$P = (0.18\ klf)\left({}^{170\ ft}/_{2}\right) = 15\ kips$$

Intermediate Bent Reaction:

$$P = (0.18\ klf)\left({}^{(170\ ft + 210\ ft)}/_{2}\right) = 34\ kips$$

Flange Lateral Bending Stress

- Construction inactive wind load = 0.18 klf
- Load per girder:

$$w = 0.18\ klf/5\ Girders = 0.036\ klf$$

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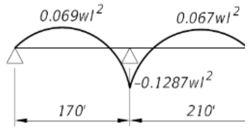
Positive Moment at 170 ft span



Moment For Each Girder:

$$M = 0.069 \times 0.036\ klf \times (170\ ft)^2 = 72\ kip \cdot ft$$

Windward Girder Between Cross-Frames:

$$M_w = {0.18\ klf \times (25\ ft)^2}/_{10} = 11\ kip \cdot ft$$

Total: 83 kip-ft

Source: AISC Moments Shears and Reactions for Continuous Highway Bridges

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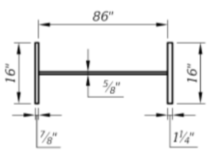
Flange Lateral Bending Stress



$$I_y = \frac{7/8 \times 16^3}{12} + \frac{86 \times (5/8)^3}{12} + \frac{1\,1/4 \times 16^3}{12}$$
$$= 727\ in^4$$

$$S = \frac{I_y}{8\ in} = 91\ in^3$$

$$f_\ell = \frac{1.25 \times M}{S} = 13.7\ ksi$$

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Strength III Load Combination

- The flange stress due to factored steel dead load is 5.2 ksi. The nominal flexural resistance of the flange (F_{nc}) is 36.7 ksi.

$$\emptyset F_{nc} = 1.0 \times 36.7\ ksi = 36.7\ ksi$$

$$f_{bu} + \frac{1}{3} f_\ell = 5.2\ ksi + \frac{1}{3} 13.7\ ksi = 9.8\ ksi$$

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Strength III Load Combination

$$\emptyset F_y = 1.0 \times 50\ ksi = 50\ ksi$$

$$f_{bu} + f_\ell = 5.2\ ksi + 13.7\ ksi = 18.9\ ksi$$

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Design Example 2 – Concrete Girder Bridge

You are designing a bridge carrying SR 856 over the Intracoastal in Miami-Dade County. The bridge consists of three simple spans with lengths of 98 feet. The superstructure consists of (5) FIB 45 beams at 12' spacing with a 2% cross-slope. Bracing will be provided only at the ends of each beam. The bottom of the girders is 30 feet above the ground and normal water elevation. Assume 1 month between when the beams are set and the deck is poured.

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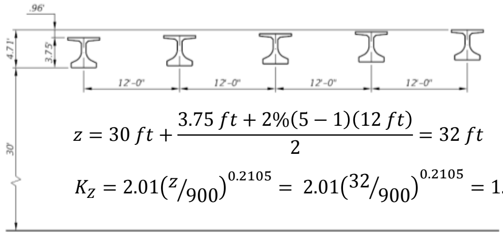
Velocity Pressure Exposure Coefficient



$$z = 30\ ft + \frac{3.75\ ft + 2\%(5-1)(12\ ft)}{2} = 32\ ft$$

$$K_Z = 2.01\left({}^{z}/_{900}\right)^{0.2105} = 2.01\left({}^{32}/_{900}\right)^{0.2105} = 1.0$$

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Gust Effect Factor

- Since span is less than 250 ft and height is less than 75 feet, G = 0.85 per SDG section 2.4.1.E

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Pressure Coefficient

- The spacing to depth ratio is:

$$ {}^{S}/_{D} = {}^{12\ ft}/_{3.75\ ft} = 3.2$$

- So, C_P = 2.0 applied to the area of the first girder, 0 for the second girder and C_P = 1.0 for girders 3-5. The wind is applied to each girder height.

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Wind Application

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What is the Construction Active Wind Speed for this Example Bridge?

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Construction Active Wind Load

For Girder 1:

$$P_Z := 2.56x10^{-6} K_Z V^2 G C_P = 2.56x10^{-6}(1.0)(20^2)(0.85)(2.0) = 0.002\ ksf$$

For Girder 2:

$$P_Z := 0\ ksf$$

For Girders 3-5:

$$P_Z := 2.56x10^{-6} K_Z V^2 G C_P = 2.56x10^{-6}(1.0)(20^2)(0.85)(1.0) = 0.001\ ksf$$

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Construction Active Wind Load

For Girder 1:

$w = (0.002\ ksf)(3.75\ ft) = 0.008\ klf$

For Girder 2:

$w = 0\ klf$

For Girder 3:

$w = (0.001\ ksf)(3.75\ ft) = 0.004\ klf$

Substructure Reaction

- Construction Inactive Wind Load:
  - w = 0.15 klf for girder 1
  - w = 0 klf for girder 2
  - w = 0.08 klf for girders 3-5

End Bent Reaction:

$$P = (0.15\ klf)\left({}^{98\ ft}/_{2}\right) + (3)(0.08\ klf)\left({}^{98\ ft}/_{2}\right)$$
$$= 19\ kips$$

Design Example 3 – Concrete Girder Bridge

Use the same location information as for example 2. The bridge consists of three simple spans with lengths of 150 feet. The superstructure consists of (7) FIB 72 beams at 10' spacing with a 2% cross-slope. Bracing will be provided at the ends and mid-span of each beam. The bottom of the girders is 30 feet above the ground and normal water elevation. Assume 1 month between when the beams are set and the deck is poured.

Wind Variables

- Velocity Pressure Exposure Coefficient, Kz = 1.0
- Gust Effect Factor, G = 0.85
- Construction Active Wind Speed, V = 20 MPH
- Basic Wind Speed for Miami-Dade County, V = 150 MPH
- Reduction Factor, R_E = 0.6,
- Construction Inactive Wind Speed, V = 90 MPH

Pressure Coefficient

- The spacing to depth ratio is:

$${}^{S}/_{D} = {}^{10\ ft}/_{6\ ft} = 1.67 < 3$$

How Should the Wind Load Be Applied for this Example?

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Wind Application

Wind Load on Cross Frames

Wind Pressures & Line Loads	Construction Inactive		Construction Active	
	Pressure	Line Load	Pressure	Line Load
Girders 1-5	0.04 ksf	0.29 klf	0.002 ksf	0.014 klf
Girders 6 and 7	0.02 ksf	0.12 klf	0.001 ksf	0.006 klf

Wind Load Applied to Cross Frames:

$$w = (0.04\ ksf)\left({}^{2.6}/_{2.0}\right)(6\ ft) = 0.31\ klf$$

$$Tributary\ Length = {}^{(150\ ft)}/_{2} = 75\ ft$$

$$P = (0.31\ klf)(75\ ft) = 23\ kips$$

End Bent Reaction:

$$= (0.29\ klf)\left({}^{150\ ft}/_{2}\right) + (2)(0.12\ klf)\left({}^{150\ ft}/_{2}\right) = 40\ kips$$

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Questions?

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For more Information:

http://www.dot.state.fl.us/structures/structuresresearchcenter/Final%20Reports/2013/BDK75-977-33_rpt.pdf

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